Beaver Ponds Environmental Education Center:

High Altitude Greenhouse

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Abstract

Growing for three seasons in a high altitude greenhouse proves to be a difficult task. High winds, high solar radiation, hail, and adverse temperatures add to the challenges above 8,000 feet (Chatt, 2017). The Beaver Ponds Environmental Education Center (BPEEC) plans to construct a high altitude greenhouse in the summer of 2017. Jeffrey Kepler worked with Eric Chatt to discuss economic costs, material sources, and technologies that need to be integrated into this greenhouse plan. After some research, the opportunity to purchase The Learning Classroom (TLC) from High Country Conservation Center (HC3) arose, and BPEEC purchased the greenhouse. BPEEC will use the materials from that greenhouse to reduce the construction costs of the greenhouse in Fairplay, Colorado. The most important technologies include the use of: a climate battery, thermal mass, fertile soil, and crop selection (Osentowski, 2015). After completion of this project, Jeffrey will perform an internship with BPEEC to help build the greenhouse and to create a high altitude guidebook.

Keywords: Greenhouse, non-profit, climate battery, thermal mass, high altitude

Beaver Ponds Environmental Education Center:

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In the beginning of the fall 2017 Semester, Jeffrey Kepler approached the Beaver Ponds Environmental Education Center (BPEEC) because they are planning to construct a high-altitude greenhouse on their property to be used as an educational tool. After the initial meeting, in February of 2017, they decided to move forward with the project. Jeffrey Kepler and Eric Chat then met every two weeks to discuss greenhouse plans, price projections, ideas for donations, and ideas for new technologies in the greenhouse. Later in the project, and opportunity to purchase the High Country Conservation Center (HC3) The Learning Center (TLC) greenhouse. This paper examines the meetings, additional research, and future for the BPEEC high altitude greenhouse project.

Biweekly Meetings with Eric Chatt

During the biweekly meetings, Jeffrey Kepler and Eric Chatt discussed greenhouse design and possibilities for the greenhouse. The most important discussion topic included materials options, since those prices would limit the possibilities for the greenhouse. BPEEC was receiving a set grant amount, so it was important to stay within the scope of that value. Next, since this was a high altitude greenhouse, special considerations needed to be considered with construction. Finally, Eric explained other considerations that needed to be considered. Overall, the weekly meetings gave the project direction and Jeffrey and Eric collaborated from February to April 2017, on this project.

The first major concern was materials options. Eric explained that the frame needed to be constructed from wood or aluminum. He explained wood is cheaper, easier to work with, and but needs to be replaced more often. Alternatively, aluminum is more expensive, more difficult to assemble, but has a longer lifetime because of increased sturdiness. The other major considerations included using polycarbonate or wood for the panels. Polycarbonate has a slightly less light transmission than glass, needs to be replaced every few years, and loses light transmission from solar decay throughout the years. Benefits of polycarbonate include: ease of installation, lower price, and ease of replacement. Alternatively, glass has better light transmission because it allows more wavelengths of light, does not cloud up over the years, and provides a sturdier structure. Downfalls of glass include: chances of breaking during installation, higher initial expense, and increased difficulty while installing (“Poly vs Glass", 2016). In the 2017 meetings with Eric Chatt, he identified many of these pros and cons.

To continue, additional considerations need to be included for constructing greenhouses at 10,000 ft. In February 2017, Eric explained the main factors include harsh winds, high solar radiation, and hail. Also, the snow is heavy and will fall off the roof on the south side of the building, which may impact the amount of solar radiation that can shine into the greenhouse. Also, high altitude greenhouses experience a shorter growing season because nighttime temperatures are colder in the late spring and early fall, which makes it difficult to maintain an appropriate temperature in the greenhouse. Finally, Eric explained that it is important to choose plant species that are temperature resistant and will thrive at a high altitude. The March 2017, visit to TLC greenhouse in Frisco, CO, showed that mixed greens, root crops, Swiss chard, snap peas, and cilantro were the best crops to grow at high altitudes (Burley, 2017). Considering these factors, additional concerns need to be considered while constructing a high altitude greenhouse.

Finally, Eric discussed that additional considerations needed be considered while constructing the greenhouse. First, pests, that include voles, chipmunks, and squirrels, needed to be considered, and a wire mesh buried under the ground would help eliminate these pests. Next, the doors need to be closed to eliminate outdoor pollination. Throughout the whole growing process, Eric wants to eliminate the use of chemicals, so this greenhouse will not create additional pollution. The most important factor for any successful greenhouse is sufficient airflow, so this will be considered in construction. Even though BPEEC wants all crops to grow, an acceptable loss needs to be integrated into the plan. Price is the final concern, since there is a budget for the project. Greenhouse kits from Greenhouses Del Sol, in 2017, range from $3,723 for an 8’ by 8’ greenhouse to $10,353 for a 12’ by 24’ greenhouse (“Greenhouses and Sunrooms”, 2017). The latter is closer to the BPEEC plan. Throughout the project, Jeffrey created an updatable Excel spreadsheet, which is available in Appendix A. By considering these additional factors, BPEEC should be able to construct a working greenhouse in the summer of 2017.

Later in the project, Jeffrey contacted HC3 to discuss high altitude greenhouses, and Jessie Burley informed him that they were selling TLC greenhouse. On March 27, 2017, Jessie Burley, Eric Chatt, and Jeffrey Kepler met at the greenhouse to consider this option. After Eric discussed the greenhouse with the BPEEC, they decided to purchase the greenhouse to repurpose the materials for the future greenhouse. This acquisition saved thousands of dollars, and will allow BPEEC to create a greenhouse with more technologies, which will allow for a longer growing season. Photos of TLC are displayed in Appendix B. Luckily, HC3 offered TLC greenhouse to BPEEC, and they purchased the greenhouse to keep the materials for educational purposes, in the local community, and for a non-profit company.

Technologies for the BPEEC Greenhouse

Climate battery and thermal mass. The climate battery is the most important technology that will be employed in the BPEEC greenhouse. This technology will increase the growing season, which will help combat the cold nights that occur in early spring and late fall. During the 1990s, Jon Cruickshank attended the Central Rocky Mountain Permaculture Institute in Basalt, Colorado. During his time, there he developed the subterranean heating and cooling system (SHCS), which involves burring perforated plastic tubing under the soil. Then the warm ambient air in the greenhouse is pumped through this tubing, which helps to keep the roots warm. The additional heat from the soil is radiated into the greenhouse at night, when solar radiation is not available. To be effective, the air needs to move through the pipes at five feet per second, or three miles per hour. Also, this technology helps keep the temperature of the greenhouse cooler during the day. One example showed a greenhouse with an air temperature of 95°F, and the outside temperature was 105°F (Osentowski, 2015). All in all, the climate battery is the most important technology that will be implemented in the BPEEC greenhouse.

A similar technology was employed in commercial greenhouses. Metal piping was run close to the ground. Hot water was then pumped through the pipes and dispersed throughout the greenhouse. This steam led to increases in ambient heat and saved costs. Fortunately, fossil fuel use decreased by 80% and costs decreased by 26% with this method. In this model, they use natural gas or other fuels to heat the water (Becerril and de los Rios, 2016). A mores sustainable option would be to use a thermal solar panel to heat the water, like BPEEC already uses on their building (Beaver Ponds, 2017). Even though BPEEC does not plan to institute this technique, it is a possibility for future greenhouses or if a remodel occurs.

Thermal heat will help maximize the effectiveness of the climate battery in the BPEEC greenhouse. Rocks will be stacked up on the northern side of the greenhouse to assist in collecting and storing heat. When the sun is at a high angle, there will be plants growing on these rocks, so they do not collect excess heat. As temperatures drop because the sun is at a lower angle, the plants will be removed so the rocks can collect heat during the day and disperse the heat at night (Osentowski, 2015). Also, five gallon buckets that are filled with compost tea will be on the north side of the greenhouse. These buckets will serve a similar purpose to the stacked rock wall (Chatt, 2017). Combining these thermal masses with the climate battery will help heat the greenhouse and will prolong the growing season in the high altitude environment.

Composting and soil. The next important technologies include on site composting and soil creation. To begin with, BPEEC already composts on their property, so they have access to quality soil that does not need to be transported to the greenhouse (Beaver Ponds, 2017). Other considerations with the soil can improve its quality. When replanting the crops, it is important to grind up the soil, so the roots can penetrate deep into the soil. Grinding the dirt at the slowest speed will produce the most productive soil (Brătucu and Păunescu, 2010). Also, adding yellow cedar sawdust can prevent Fusarium oxysporum f. sp. radicis-lycopersici, which causes rot in beefsteak tomatoes (Cheuk et al, 2005). Adding these techniques to the already fertile compost, will produce the healthiest soil.

The BPEEC will also be vermicomposting under the walkways in the greenhouse. Eric explained that there will be wooden pallets on the walkway, and under these pallets will be a worm farm. BPEEC can use the worm castings in the soil of the plants to increase the soil fertility (Osentowski, 2015). BPEEC also plans to educate people on vermicomposting and to give people vermicomposting starter packs from the existing worms in the greenhouse. Including a vermicomposting system will help improve soil fertility and assist in educational opportunities.

Another important aspect of soil health is the mycelium contained in the soil. Mycelium is a fungus that helps break down soils and spread nutrients to the plants. Eric plans to shop for spores to inoculate the soil with. He plans to use local strains to maximize the effectiveness of the soil at high altitudes (Chatt, 2017). Since soil is one of the most important factors for a greenhouse, it is important to use the best quality fungus.

Finally, the BPEEC will create the best soil by using raised beds. Having the beds raised off the ground decreases the chances that the roots will freeze early and late in the growing season. Also, this adds additional thermal mass (Osentowski, 2015). Ergonomics are also improved with this design because people will not have to bend over as much. The raised beds also give classes a place to sit while they are in the greenhouse (Chatt, 2017).

North wall nursery. To increase the yields in the greenhouse, the BPEEC could use a north wall nursery. The effectiveness of a dual purpose greenhouse has been studied in the academic journal by Sethi and Dubey in 2011. They discussed that creating a greenhouse with two sections is the most profitable. On the floor, a traditional greenhouse system should be implemented. On the north wall, small plants can be stacked up, so they all receive light. When these plants are large enough, they can replace plants that are growing in the rest of the greenhouse. The study showed that these greenhouses decreased the return on investment from five years, without a dual purpose greenhouse, to under two years (Sethi and Dubey, 2011). With the short growing season, this would be a good option for the BPEEC to increase yields in their greenhouse.

Winter dormancy. The final technology that needs to be considered is winter dormancy. Eric discussed that a four season greenhouse is not an option (2017). All year operations require large energy inputs to keep the greenhouse warm. An example from arctic greenhouses state that it costs 50 cents per kWh to heat a greenhouse. Also, water scarcity becomes a concern (Armstrong, 2017). Since the BPEEC does not want to spend money to heat the greenhouse this is not an option. Therefore, BPEEC needs to plan for winter dormancy by knowing which plants are annuals, will die each year, and which plants are perennials, will come back each year. When the greenhouse is not in use, it can be used for additional storage, since it will keep objects dry during the snowy months (Osentowski, 2015). With a larger budget, the BPEEC could implement a greenhouse that operates in the winter months.

Internship with BPEEC

Now that the BPEEC greenhouse is planned and materials were sourced from TLC from HC3, there are many steps that must be included to ensure the greenhouse will be constructed. Jeffrey is planning on participating in an internship in the 2017 summer to help build the greenhouse and to create a publishable guidebook, so people have a resource to construct high altitude greenhouses. During construction, Jeffrey will take photos and help in construction, so he can assemble the guidebook. Since no resources focus on constructing greenhouses at high altitude, this will offer a valuable resource for people that live above 8,000 feet.

The first steps to construct the greenhouse involve deconstructing and moving TLC from Frisco, Colorado, to Fairplay, Colorado. Eric, Jeffrey, and other volunteers will need to break down the existing greenhouse and transport it in pieces to Fairplay. Once the pieces are all in Fairplay, BPEEC will need to dig the foundation for the greenhouse, so the mesh wire, for pest control, and the plastic tubing, for the climate battery, can be buried in the soil. Also, posts with concrete will be set in the ground to ensure a solid foundation for the greenhouse. Another baseline step, includes running pipes from the well, so the greenhouse can have access to the water (Chatt, 2017). After, TLC has been moved and a foundation is complete, construction of the greenhouse can begin.

Once these preliminary steps are complete, additional materials need to be obtained for the greenhouse. The large expenses include: a garage door, multiple intake fans, and metal roofing for the north wall. During deconstruction of TLC, some materials may break, so additional lumber and polycarbonate panels will need to be purchased. Finally, rocks for the thermal mass, five gallon buckets for thermal mass, and pallets for walkways need to be purchased. Finally, fungus for the soil and seeds for the plants need to be purchased for the first season, which will be in 2018. Unforeseen, materials may need to be required, but these are the materials that Eric predicted would be needed for the greenhouse (2017).

After completion of the greenhouse, BPEEC will use the greenhouse as an educational tool. Currently, the facility studies sustainable agriculture, sustainable energy, and environmental research and management. Also, educational opportunities for K-12, the "SnowSchool Winter Program", and college internships are available (Beaver Ponds, 2017). A brochure about BPEEC is included in Appendix D. Adding the greenhouse to the facility, will provide another resource for research and education at BPEEC.

Conclusion

In conclusion, Jeffrey worked with BPEEC over the Spring 2017 semester to help develop a high altitude greenhouse. Eric Chatt already had basic plans for the greenhouse (Appendix C), so he imparted his knowledge onto Jeffrey. Then Jeffrey created a pricing sheet to determine the approximate cost of a greenhouse. After contacting HC3, Jeffrey passed along the opportunity, so BPEEC could purchase TLC. Some negotiations occurred and BPEEC obtained the greenhouse to help in construction of the planned greenhouse. Using technologies like the climate battery, thermal masses, fertile soil, and raised beds will allow BPEEC to have a greenhouse that will be operational for three seasons at 10,000 feet. Jeffrey will perform an internship with BPEEC in the summer of 2017, to help construct the greenhouse and to develop a guidebook. In the future, BPEEC will use the greenhouse and guidebook to educate people on high altitude greenhouse construction and operation. Since there is no available resource, this guidebook will fit a need that is missing for high altitude agriculture.

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Appendix A

This Excel spreadsheet was created for BPEEC to estimate the total cost of materials for the greenhouse. Prices could be updated and quantities could be updated to give an overall cost if inputs changed.

BPEEC: High Altitude Pricing Sheet				
Materials	Unit Size	Quantity	Price per unit	Total Price
Polycarbonate panels (16mm)	4'x12'	12	$ 232.00	$ 2,784.00
Wood				$ -
2X12	16 foot	30	$ 24.85	$ 745.50
2X8	12 foot	15	$ 10.92	$ 163.80
2X4	12 foot	10	$ 5.48	$ 54.80
4X4 treated lumber	12 foot	20	$ 16.97	$ 339.40
Ridge I-beam	1 beam	1	$ 2,000.00	$ 2,000.00
Ducting/piping for climate battery		12	$ 14.47	$ 173.64
Concrete	1 bag	35	$ 4.00	$ 140.00
Cement	1 bag	20	$ 10.76	$ 215.20
Cement mixer	1 mixer	1	$ 299.00	$ 299.00
Hardware				
Nails		1	$ 200.00	$ 200.00
Screws				$ -
Roof Screws (per 300)	1 box	1	$ 95.94	$ 95.94
Other wood screws				$ -
Bolts		1	$ 100.00	$ 100.00
Brackets for polycarb panels		1	$ 500.00	$ 500.00
Rafter Hangers (40/140 degree)		52	$ 3.00	$ 156.00
Paint/oil helmsman	128 fl oz	5	$ 39.96	$ 199.80
Tar				$ -
Ty-vek (3'x100')	1 roll	1	$ 43.96	$ 43.96
Caulk (silicone)	1 tube	24	$ 5.28	$ 126.72
Bituthene (200 sf)	1 roll	3	$ 163.00	$ 489.00
Pex Line	100 feet	3	$ 28.52	$ 85.56
Flasing for roof				$ -
Flashing for walls				$ -
Doors				
Garage door	1 door	1	$ 299.00	$ 299.00
Regular door	2 door	1	$ 100.00	$ 100.00
Metal roofing	2'x12'	20	$ 24.34	$ 486.80
Fans		1	$ 500.00	$ 500.00
Wire mesh and wire ties	2'x50'	6	$ 25.97	$ 155.82
Gravel	1 load	1	$ 100.00	$ 100.00
Sand	2 load	1	$ 100.00	$ 100.00
Other				
Total			$ 4,947.42	$ 10,653.94

Appendix B

These photos represent the TLC at the former HC3 property in Frisco, Colorado.

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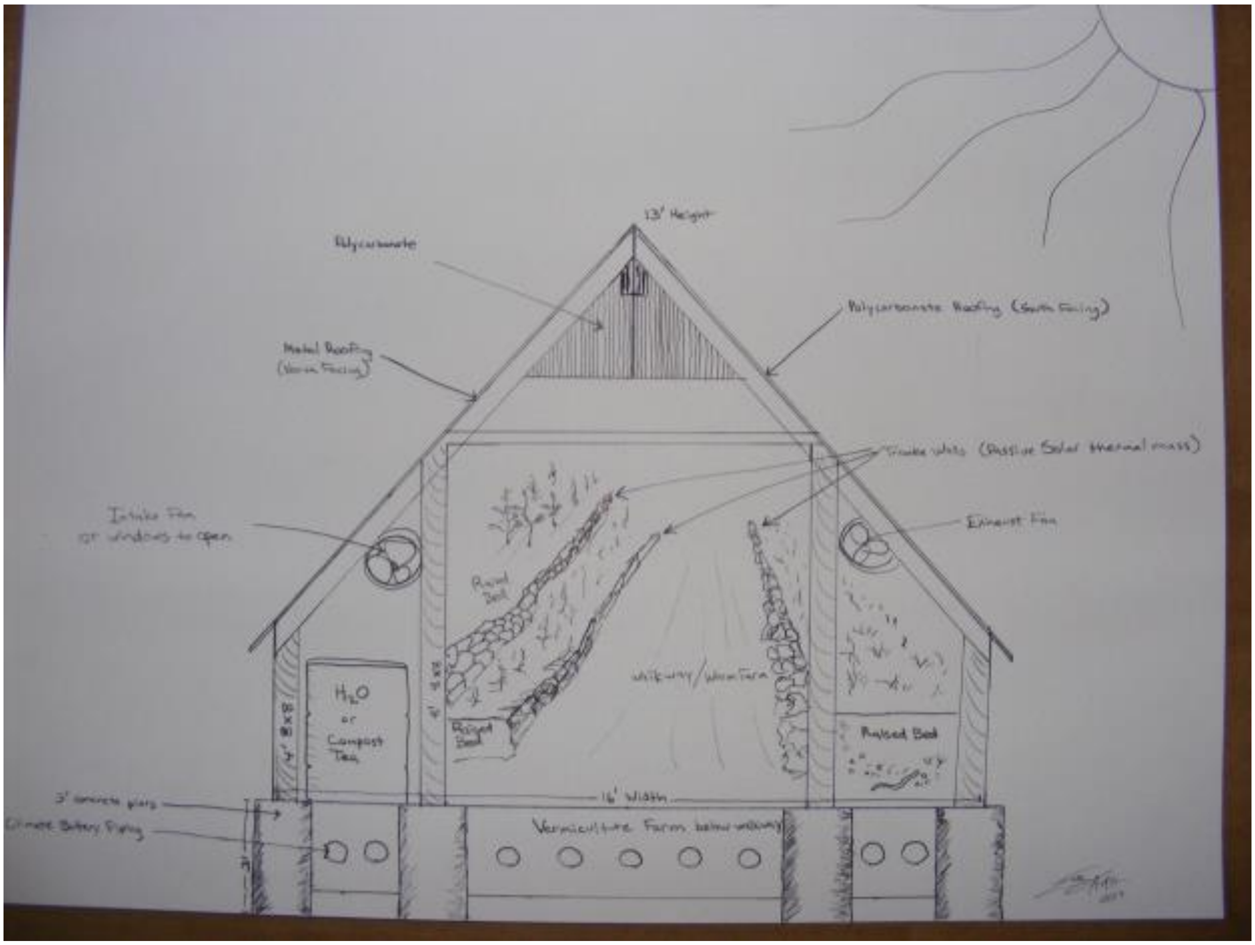
Appendix C

These are the drawings for the proposed BPEEC greenhouse that Eric Chatt created for the presentation.



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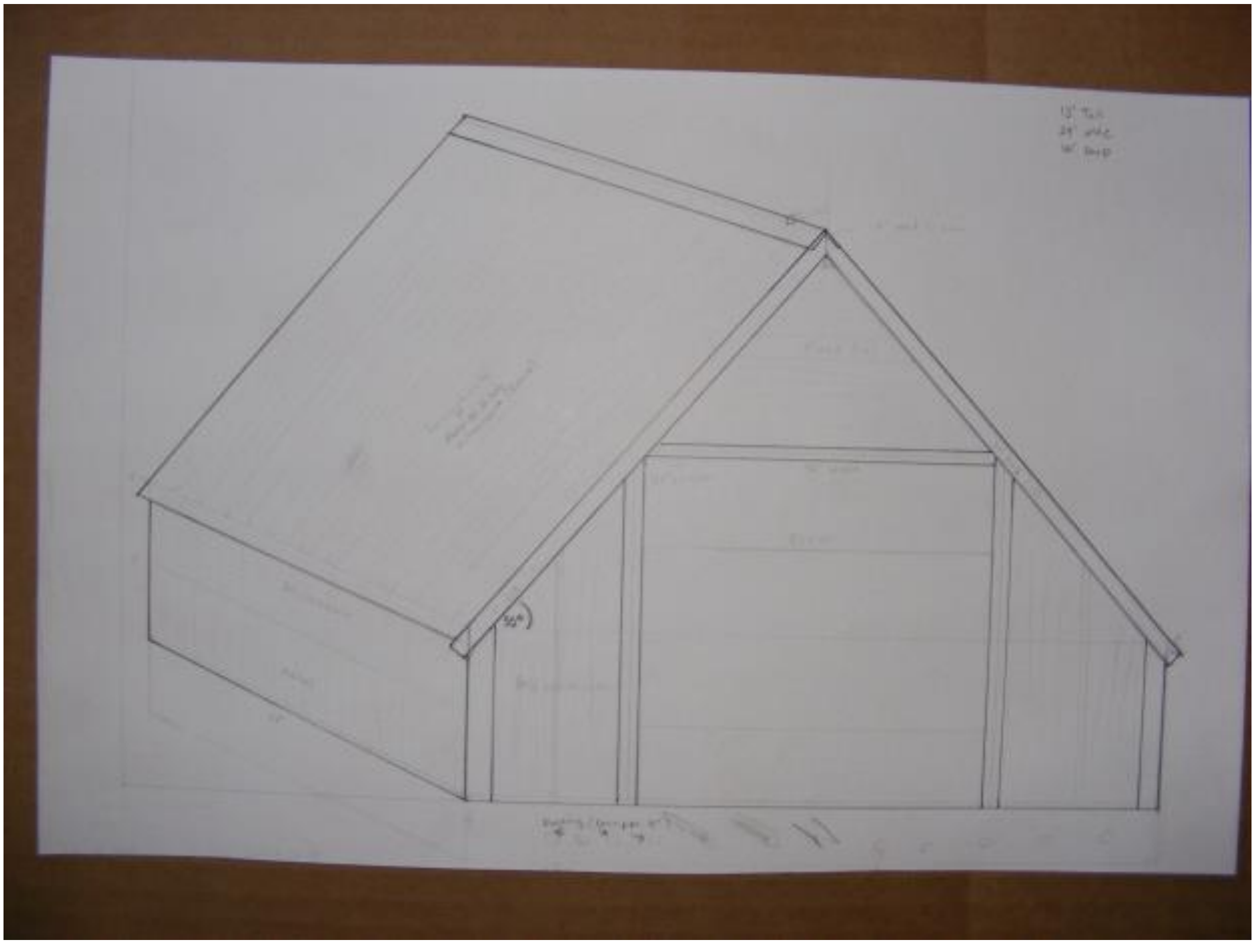

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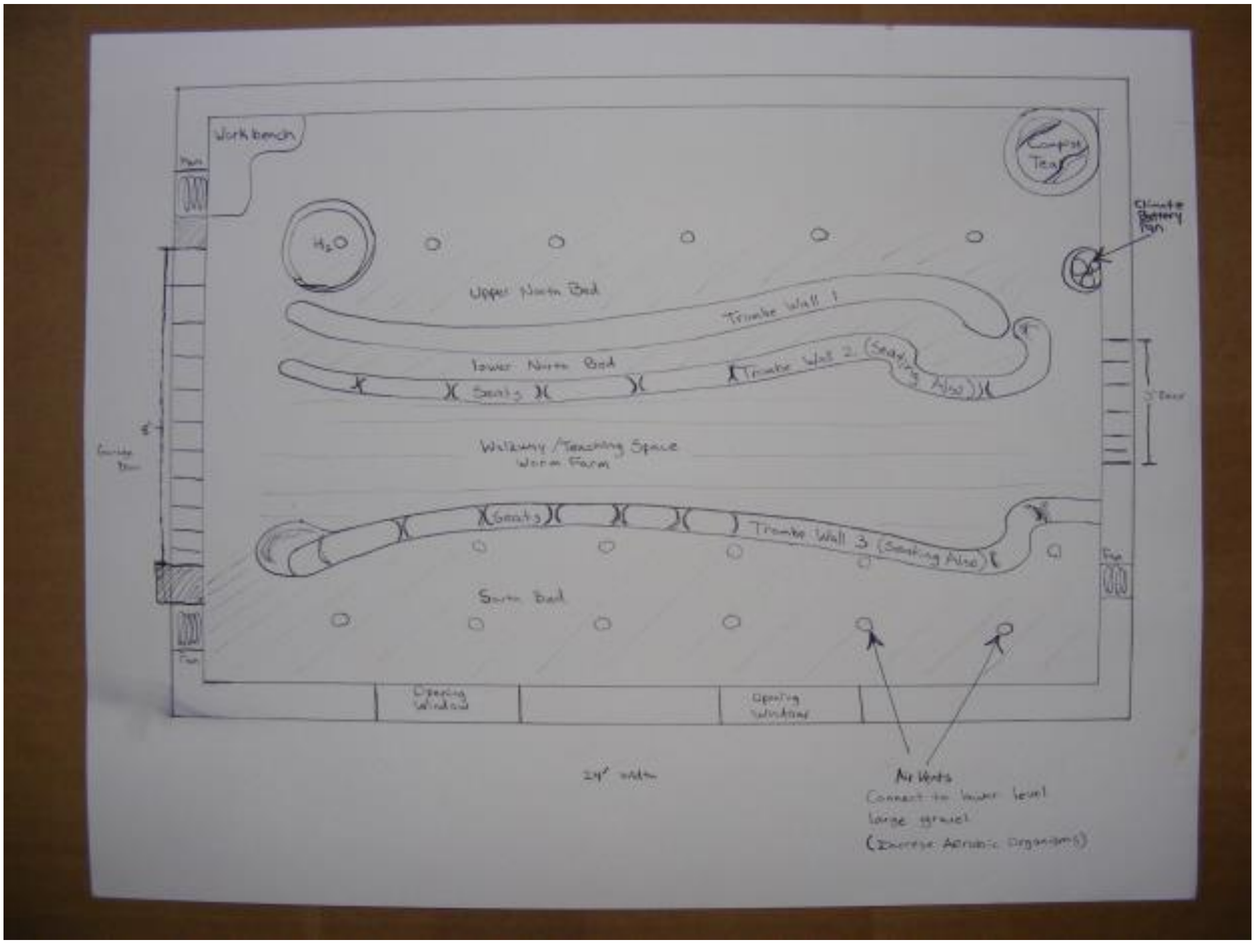

Appendix D

Copy of the BPEEC brochure that was used during the Colorado Mountain College Sustainability Conference presentation.

Sustainable Agriculture

A multitude of sustainable living and learning opportunities exist at the Center. Topics include high alpine ecosystems, high altitude gardening, alternative energy, alpaca, goat and chicken husbandry, fiber production, edible mushroom propagation, local, native healing plants, wildflowers and pollinators, beaver and riparian ecosystems, and forest management.

Look for our farmer's market coming this summer.

Beaver Ponds Environmental Education Center. We are open by appointment only. Please call or email us soon to schedule a visit .We'd love to show you around.

Phone: 719-838-0143
E-mail: info@beaverponds.org

Beaver Ponds Environmental Education Center

We help people of all ages learn about domestic livestock, horticulture, green energy generation and environmental conservation in a high-alpine, natural setting at Sacramento Creek Ranch near Faiplay, Colorado.

We provide tours, seminars, workshops, research space, and field trips for all ages.

Beaverponds.org

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Copy of the BPEEC brochure that was used during the Colorado Mountain College Sustainability Conference presentation.

High Alpine Ecosystem Conservation

Located on over 70 acres, Beaver Ponds borders the Pike National Forest. Interpretive trails offer stunning views of the Mosquito Range while winding through evergreen forest, riparian zones filled with beaver ponds and sagebrush shrub lands.

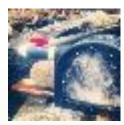
An assortment of flora and fauna call Sacramento Creek home. The different ecosystems create perfect habitat for wildflowers, alpine trees and shrubs, beavers, elk, deer and numerous birds.

History

With the remains of the 1800's Duquesne smelter on the property, the Center fits right in with the history the surrounds it.

Renewable Energy and Sustainability

Built with the Earth in mind, Beaver Ponds utilized local, recycled and repurposed material in construction. Alternative energy systems offer exciting learning opportunities incorporating a micro hydro turbine, wind turbine, solar photovoltaic panels, thermal solar panels and in-ground geo-thermal.



Electricity and heat for the classroom areas, director's quarters and garage are provided entirely by renewable means. On the few days when the alternative heat radiant floor system is not enough, a wood heating stove warms the living quarters with wood gleaned from the property's fire mitigation processes.

Sustainable Agriculture

We demonstrate numerous aspects of sustainable agriculture. Our uniquely constructed passive solar greenhouse is designed to absorb solar heat during the day and slowly release it at night. Compost from our farm animals serves as organic fertilizer for greenhouse plants. We us a micro-fodder system to grow fresh grass for our animals.

We have alpacas, goats and a llama to demonstrate growing animals for fiber. Our chickens are all heritage breeds, meaning they retain the original, healthy genetic material of "old fashioned" chickens.